Predictions of Soft Processes at the LHC Implemented in PYTHIA8

Konstantin Goulianos*

The Rockefeller University

arXiv.org > hep-ph > arXiv:1205.1446

High Energy Physics - Phenomenology

MBR Monte Carlo Simulation in PYTHIA8

R. Ciesielski, K. Goulianos

(Submitted on 7 May 2012)

* with:
Robert Ciesielski

1

CONTENTS

INTRODUCTION

- This is an adaptation of the MBR (Minimum Bias Rockefeller) simulation RENORM to PYTHIA8.
  - successfully tested at Fermilab fixed target and collider experiments.
- RENORM predictions are based on a parton model approach, in which diffraction is derived from inclusive PDFs and color factors.
- Gap Cross Sections:
  - Gap cross sections vs gap width:
    - ✓ Absolute normalization!
  - Hadronization of dissociated proton:
    - Implemented by introducing a (non-perturbative) "quark string" and tuning it to reproduce the MBR multiplicity and p_T distributions.
    - $dN/d\eta$, p_T, and particle ID (new in this implementation; the original MBR produced only $\pi^{\pm}$ and π^0)
  - Unique unitarization procedure based on a saturated exchange.
- Total Cross section: based on a saturated Froissart bound leading to a $\ln^2 s$ dependence.
  - Immune to eikonaalization models that plague the field!

STUDIES OF DIFFRACTION IN QCD

Non-diffractive

- color-exchange ➔ gaps exponentially suppressed

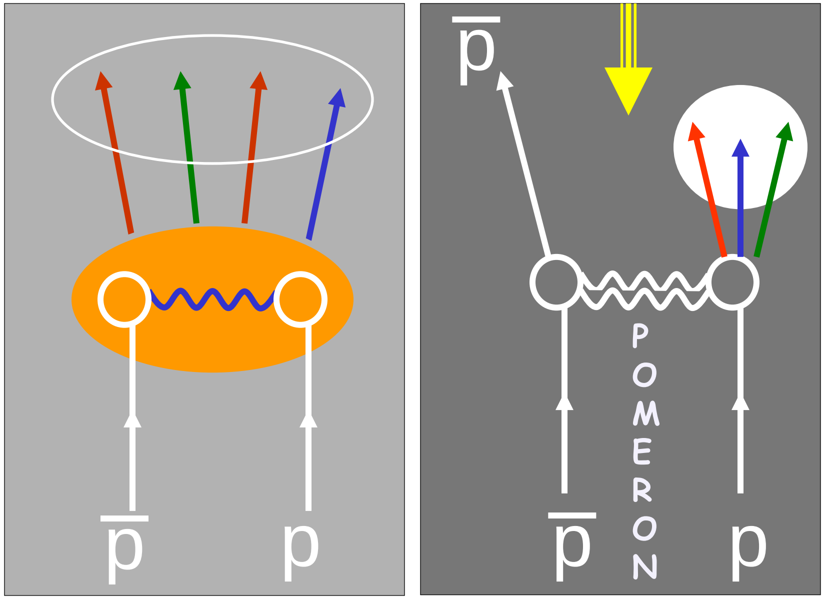
Diffractive

- Colorless vacuum exchange
➔ large-gap signature

rapidity gap

Incident hadrons acquire color and break upart

CONFINEMENT

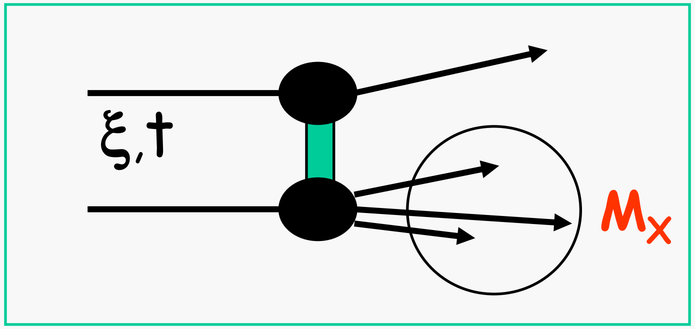


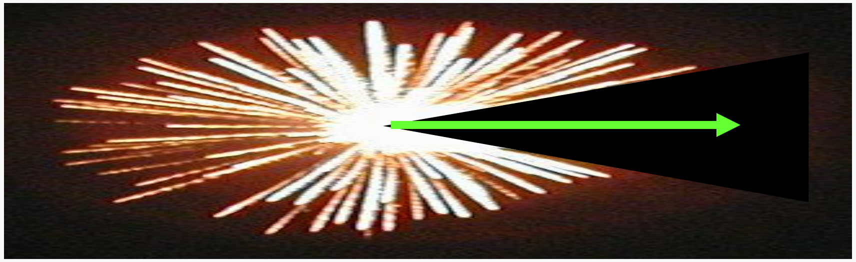
Incident hadrons retain their quantum numbers remaining colorless

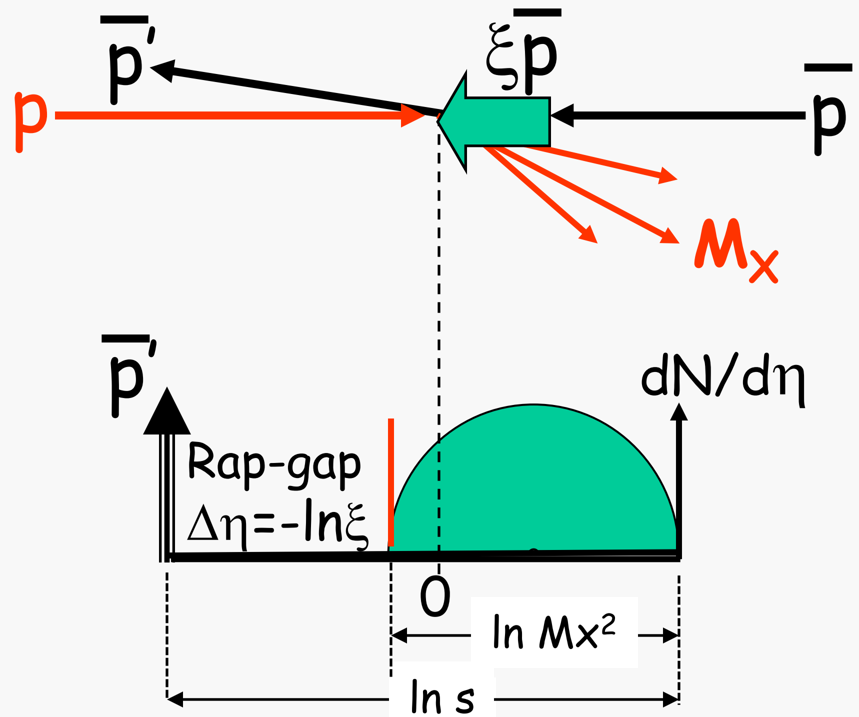
Goal: probe the QCD nature of the diffractive exchange

DEFINITIONS

SINGLE DIFFRACTION







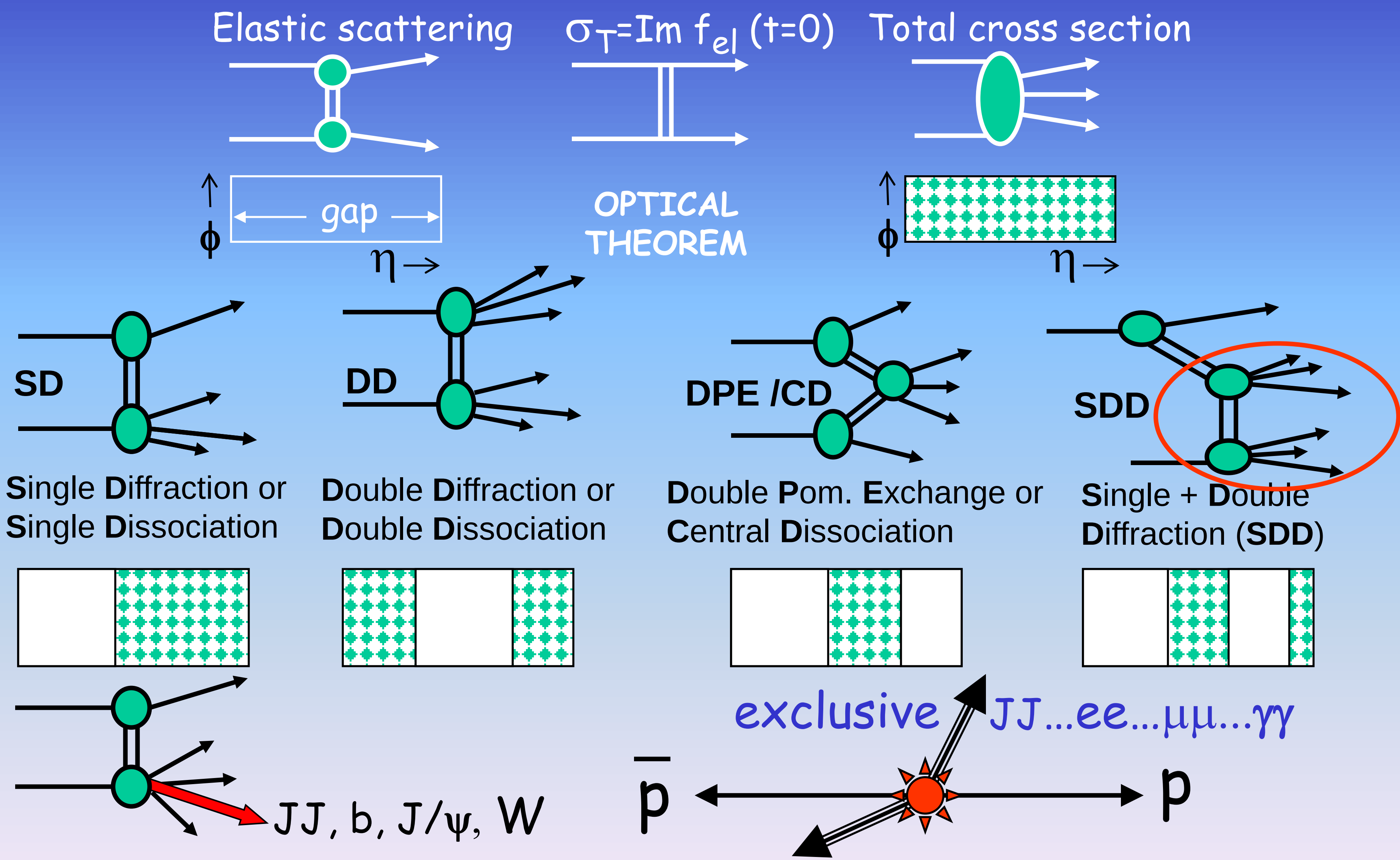
$$1 - x_L \equiv \xi = \frac{M_X^2}{s}$$

$$\xi^{CAL} = \frac{\sum_{i=1}^{all} E_T^{i\text{-}tower} e^{-\eta_i}}{\sqrt{s}}$$

since no radiation →
no price paid for increasing diffractive gap size

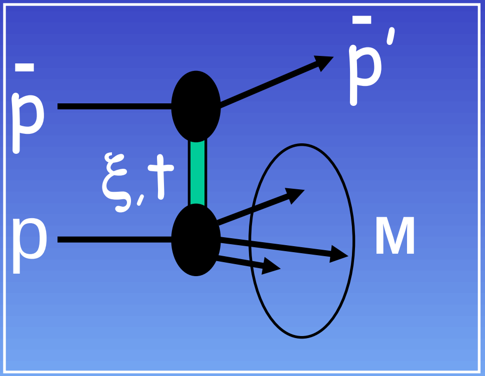
$$\left(\frac{d\sigma}{d\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \Rightarrow \frac{d\sigma}{dM^2} \propto \frac{1}{M^2}$$

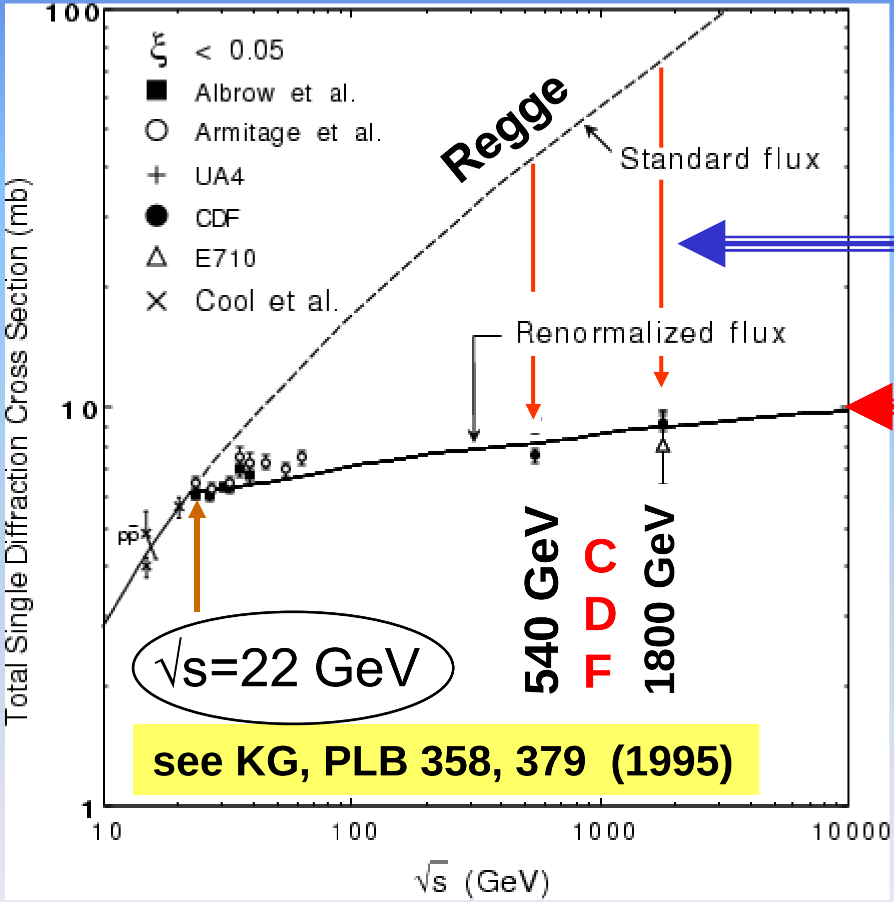
DIFFRACTION AT CDF



FACTORIZATION BREAKING IN SOFT DIFFRACTION

➔diffractive x-section suppressed relative to Regge prediction as √s increases



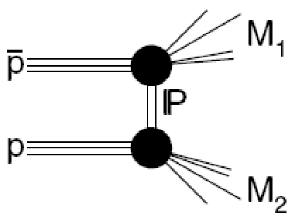


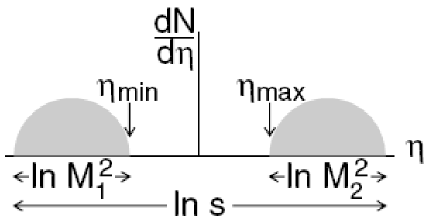
Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

RENORMALIZATION

❑ **Question:**
does factorization breaking affect *t*-distributions?

DD at CDF

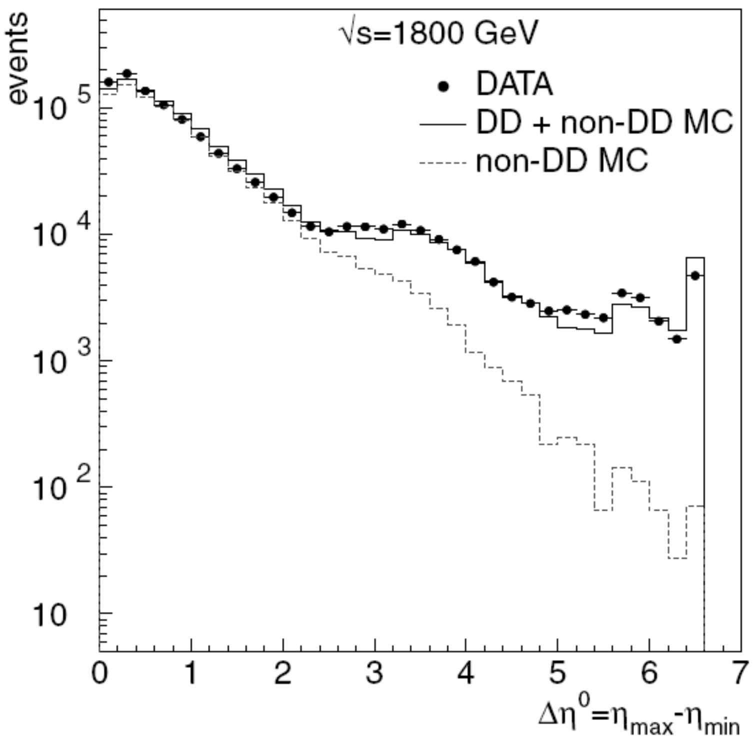


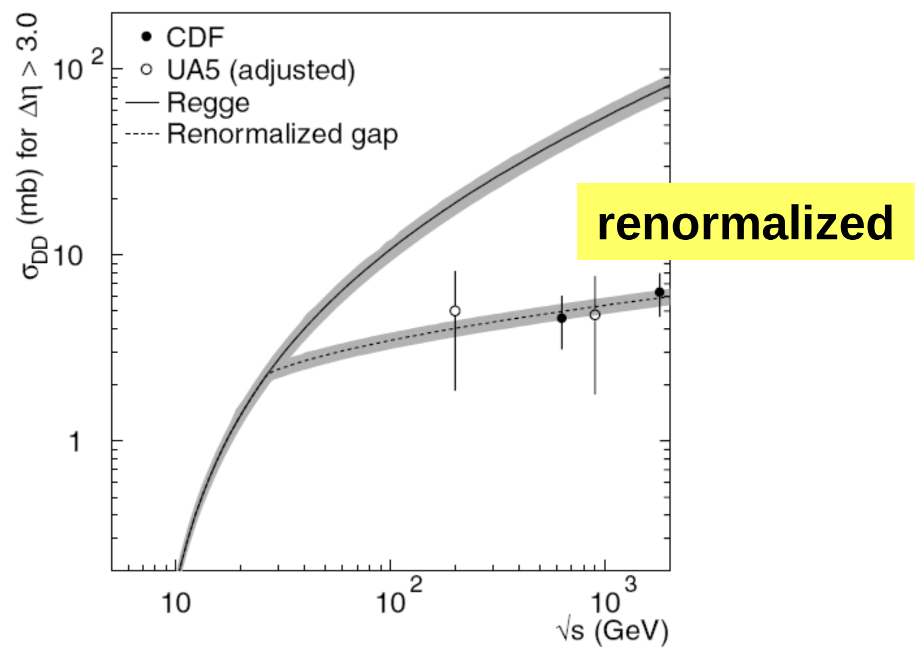


$$\frac{d^3\sigma_{\rm DD}}{dt\,dM_1^2\,dM_2^2} = \frac{d^2\sigma_{\rm SD}}{dt\,dM_1^2}\,\frac{d^2\sigma_{\rm SD}}{dt\,dM_2^2}\Big/\frac{d\sigma_{el}}{dt}$$
$$= \frac{[\kappa\beta_1(0)\beta_2(0)]^2}{16\pi}\;\frac{s^{2\epsilon}e^{b_{\rm DD}t}}{(M_1^2M_2^2)^{1+2\epsilon}}$$

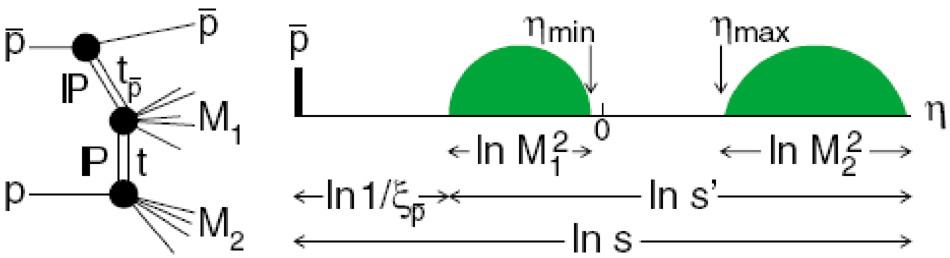
$$\frac{d^3\sigma_{\rm DD}}{dt\,d\Delta\eta\,d\eta_c} = \left[\frac{\kappa\beta^2(0)}{16\pi}\,e^{2[\alpha(t)-1]\Delta\eta}\right]\left[\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right]$$

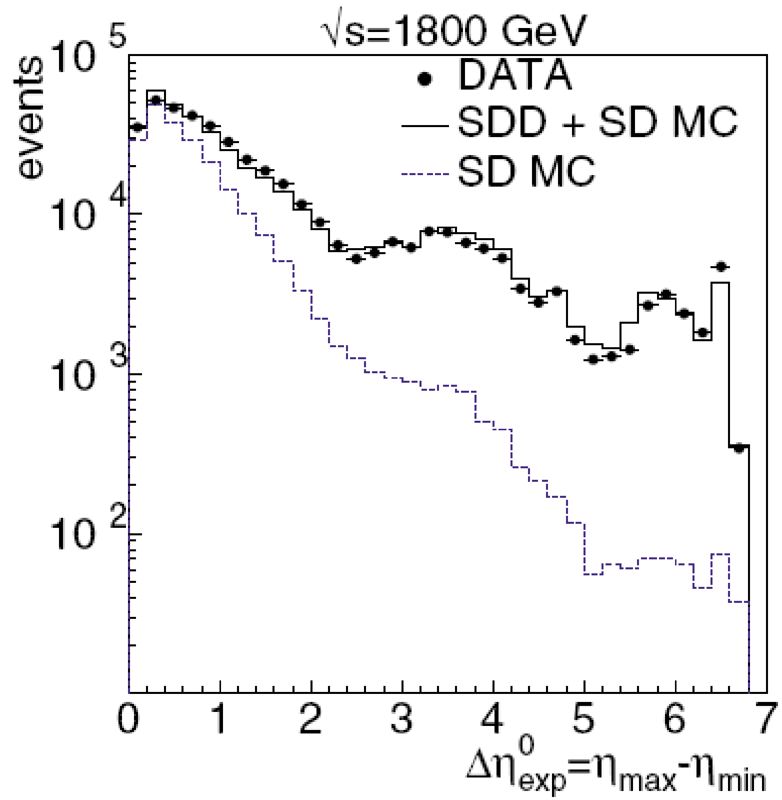
gap probability x-section





SDD at CDF

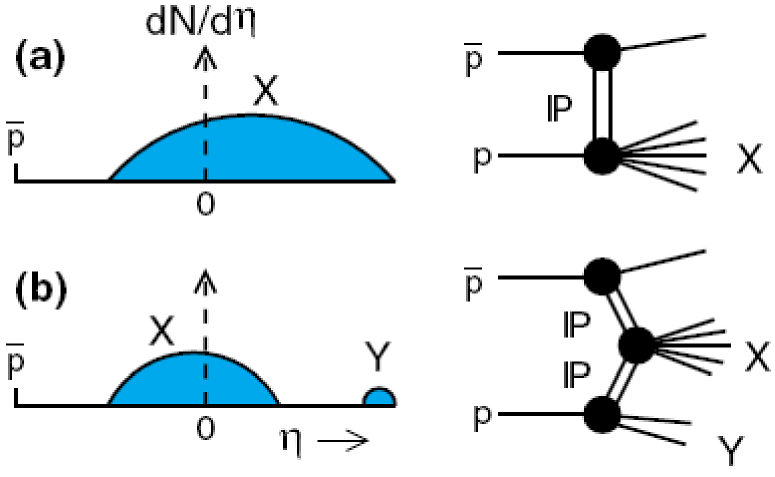




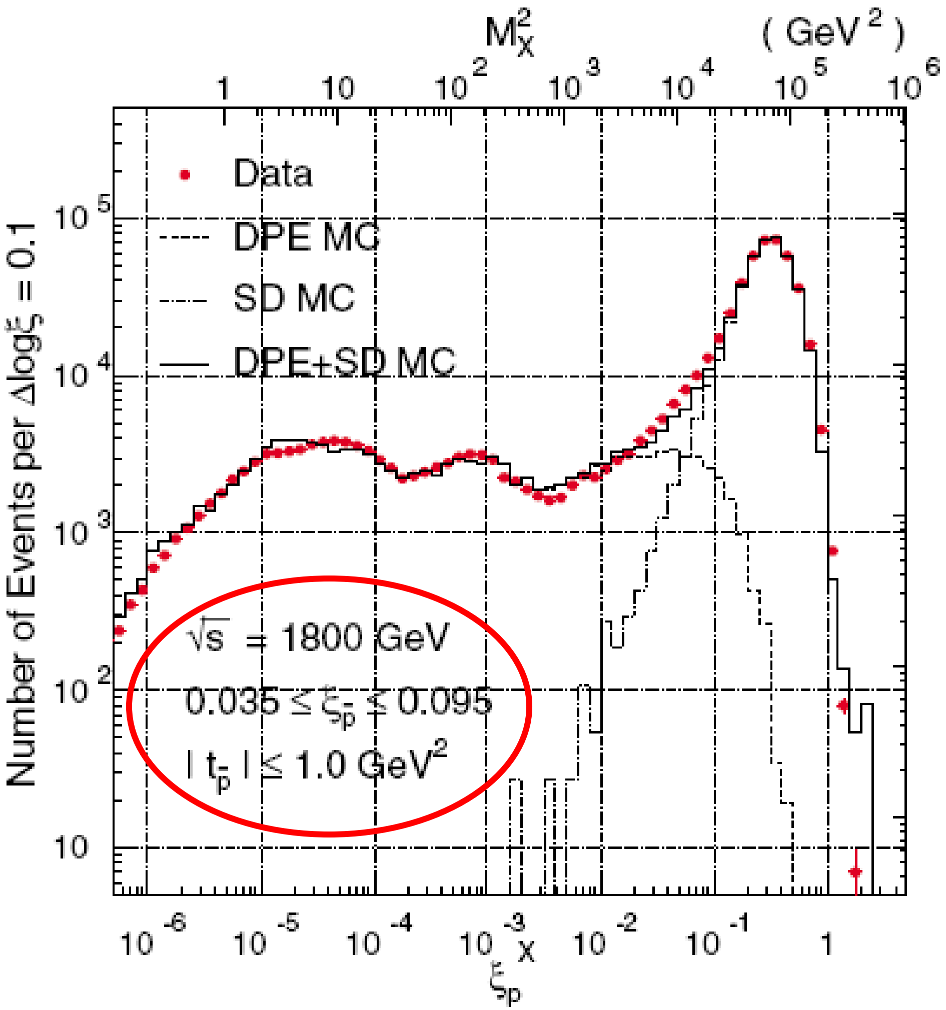
- Excellent agreement between data and MBR (MinBiasRockefeller) MC

$$\frac{d^5\sigma}{dt_{\bar p}\,dt\,d\xi_{\bar p}\,d\Delta\eta\,d\eta_c} = \left[\frac{\beta(t)}{4\sqrt{\pi}}\, e^{[\alpha(t_{\bar p})-1]\ln(1/\xi)}\right]^2 \times \kappa\left\{\kappa\left[\frac{\beta(0)}{4\sqrt{\pi}}\, e^{[\alpha(t)-1]\Delta\eta}\right]^2 \kappa\left[\beta^2(0)\left(\frac{s''}{s_\circ}\right)^{\epsilon}\right]\right\}$$

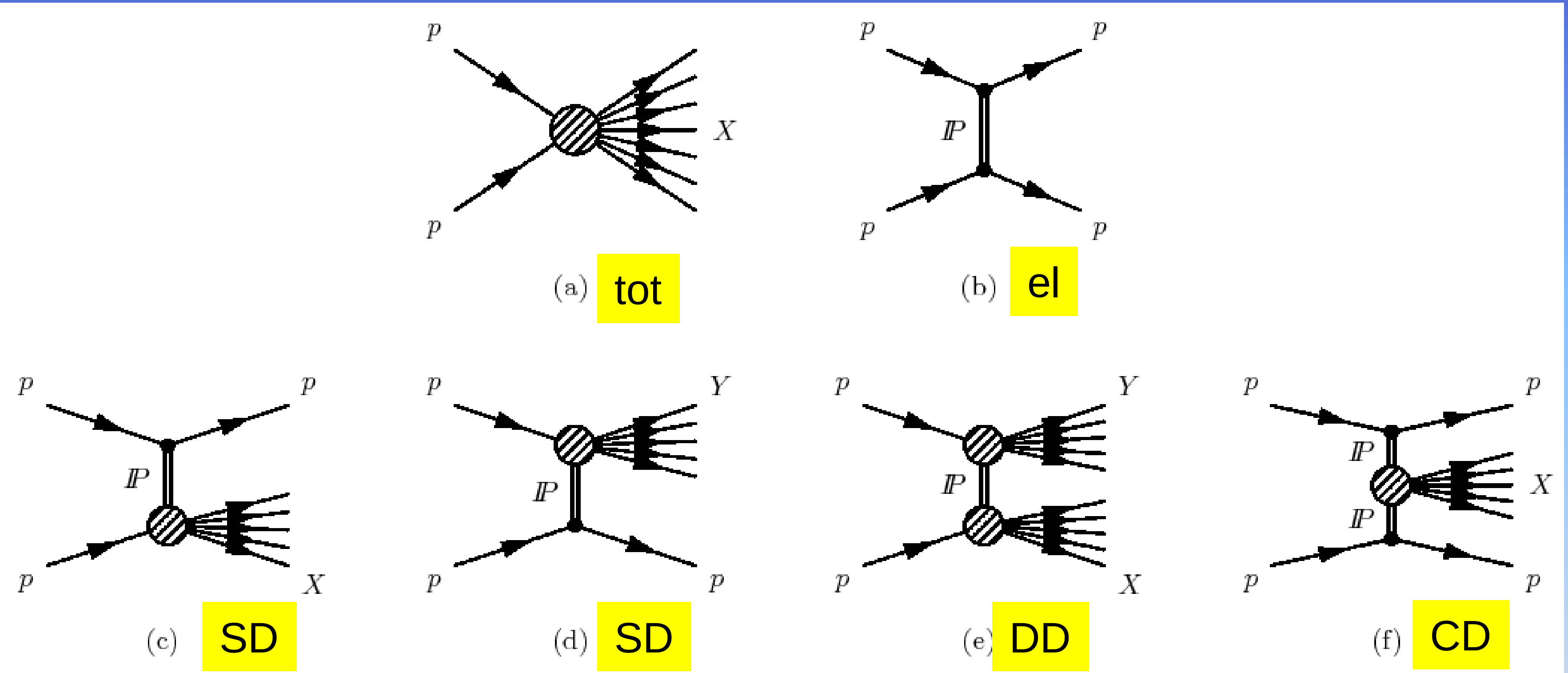
CD (DPE) at CDF



- Excellent agreement between data and MBR
➔ low and high masses are correctly implemented



Cross Sections



- SD → single diffraction (single dissociation)
- DD → double dissociation (double diffraction)
- CD → central dissociation (double pomeron exchange)

Total, elastic, and inelastic x-sections

$$\sigma_{\mathrm{ND}} = (\sigma_{\mathrm{tot}} - \sigma_{\mathrm{el}}) - (2\sigma_{\mathrm{SD}} + \sigma_{\mathrm{DD}} + \sigma_{\mathrm{CD}})$$

R. J. M. Covolan, K. Goulianos, J. Montanha, Phys. Lett. B **389**, 176 (1996)

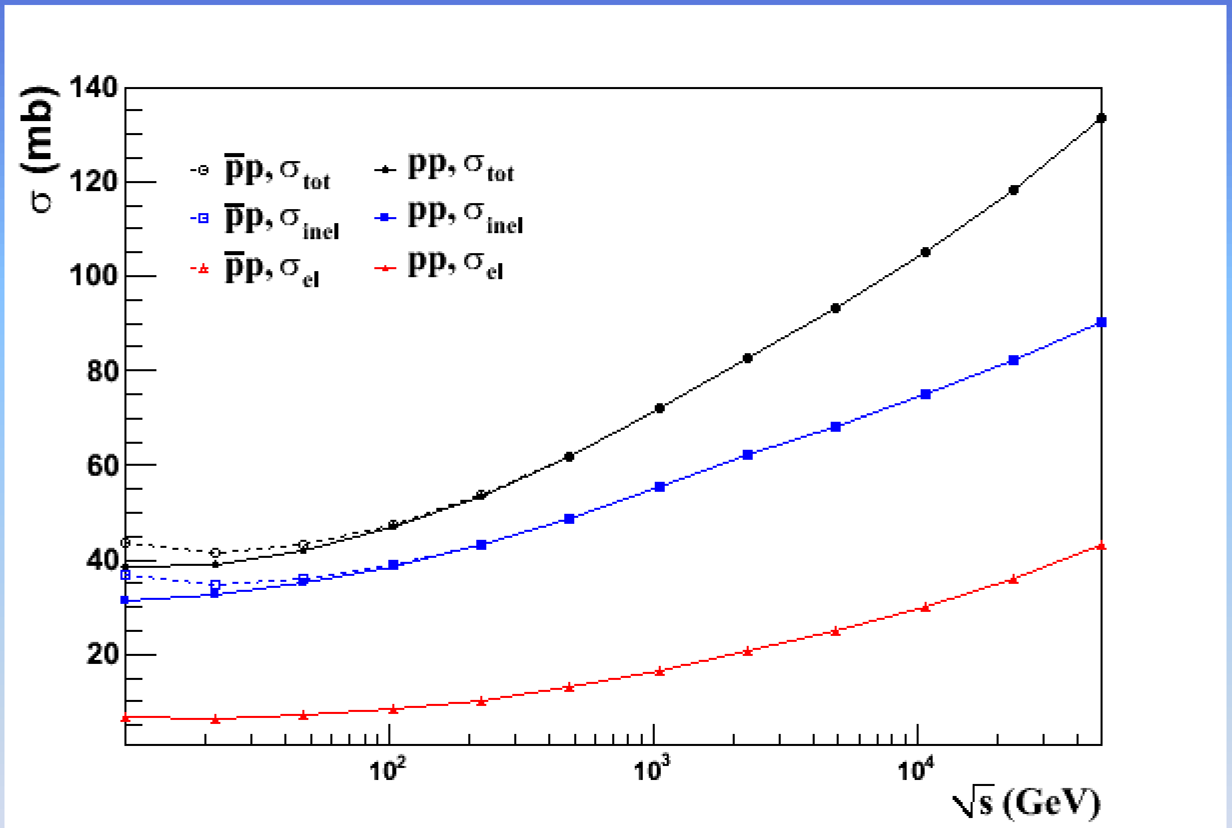
$$\sigma_{\mathrm{tot}}^{p^{\pm}p} = \begin{cases} 16.79 s^{0.104} + 60.81 s^{-0.32} \mp 31.68 s^{-0.54} & \text{for } \sqrt{s} < 1.8 \\ \sigma_{\mathrm{tot}}^{\mathrm{CDF}} + \frac{\pi}{s_0}\left[\left(\ln\frac{s}{s_F}\right)^2 - \left(\ln\frac{s^{\mathrm{CDF}}}{s_F}\right)^2\right] & \text{for } \sqrt{s} \geq 1.8 \end{cases}$$

K. Goulianos, *Diffraction, Saturation and pp Cross Sections at the LHC*, arXiv:1105.4916.

$$\sqrt{s^{\mathrm{CDF}}} = 1.8\ \mathrm{TeV},\ \sigma_{\mathrm{tot}}^{\mathrm{CDF}} = 80.03 \pm 2.24\ \mathrm{mb}$$

$$\sqrt{s_F} = 22\ \mathrm{GeV} \qquad s_0 = 3.7 \pm 1.5\ \mathrm{GeV}^2$$

Total, elastic, and inelastic x-sections versus √s



Difractive x-sections

$$\frac{d^2\sigma_{SD}}{dt\,d\Delta y} = \frac{1}{N_{\rm gap}(s)}\left[\frac{\beta^2(t)}{16\pi}e^{2[\alpha(t)-1]\Delta y}\right]\cdot\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\},$$

$$\frac{d^3\sigma_{DD}}{dt\,d\Delta y\,dy_0} = \frac{1}{N_{\rm gap}(s)}\left[\frac{\kappa\beta^2(0)}{16\pi}e^{2[\alpha(t)-1]\Delta y}\right]\cdot\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\},$$

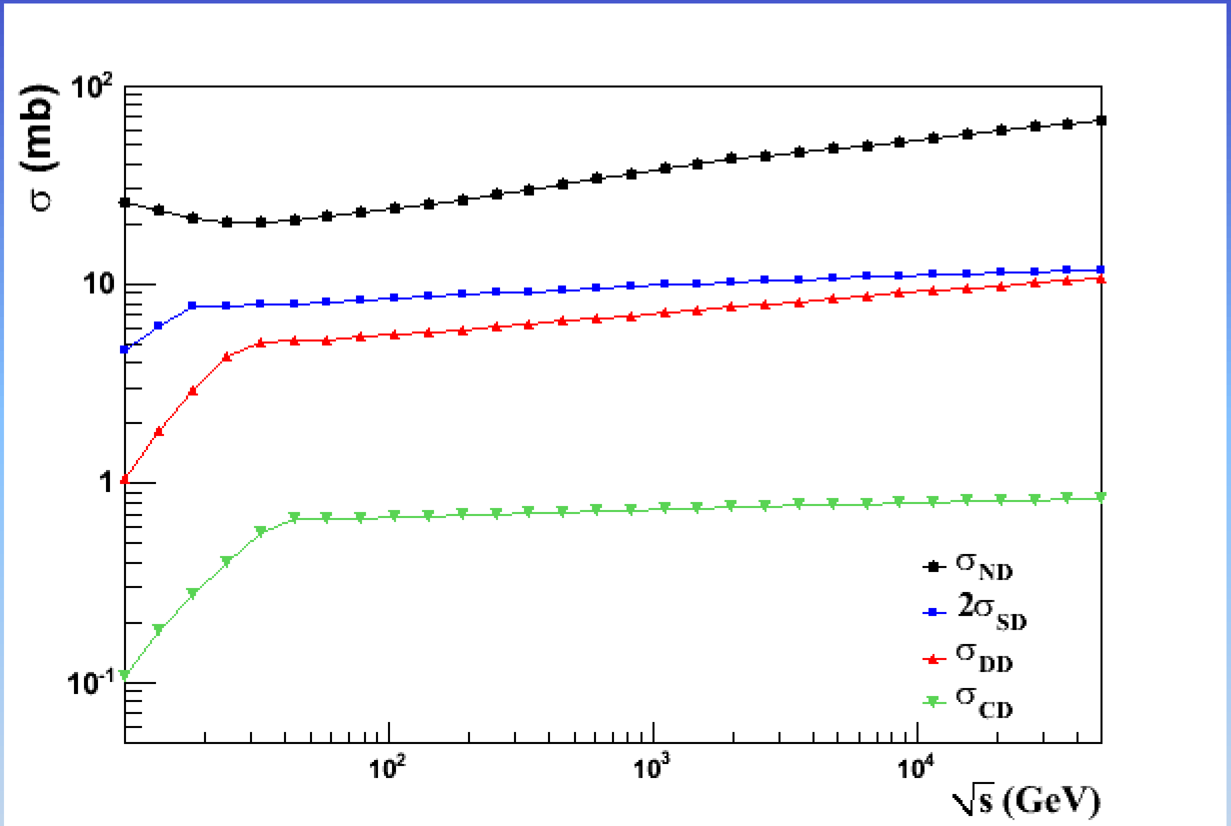
$$\frac{d^4\sigma_{DPE}}{dt_1\,dt_2\,d\Delta y\,dy_c} = \frac{1}{N_{\rm gap}(s)}\left[\Pi_i\left[\frac{\beta^2(t_i)}{16\pi}e^{2[\alpha(t_i)-1]\Delta y_i}\right]\right]\cdot\kappa\left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\}$$

$$\beta^2(t) = \beta^2(0)F^2(t)$$

$$F^2(t) = \left[\frac{4m_p^2 - 2.8t}{4m_p^2 - t}\left(\frac{1}{1-\frac{t}{0.71}}\right)^2\right]^2 \approx a_1 e^{b_1 t} + a_2 e^{b_2 t}$$

α_1=0.9, α_2=0.1, b_1=4.6 GeV^{-2}, b_2=0.6 GeV^{-2}, $s'=s\,e^{-\Delta y}$, κ=0.17, $\kappa\beta^2(0)=\sigma_0$, s_0=1 GeV^2, σ_0=2.82 mb or 7.25 GeV^{-2}

Difractive x-sections of $\sqrt{s}$

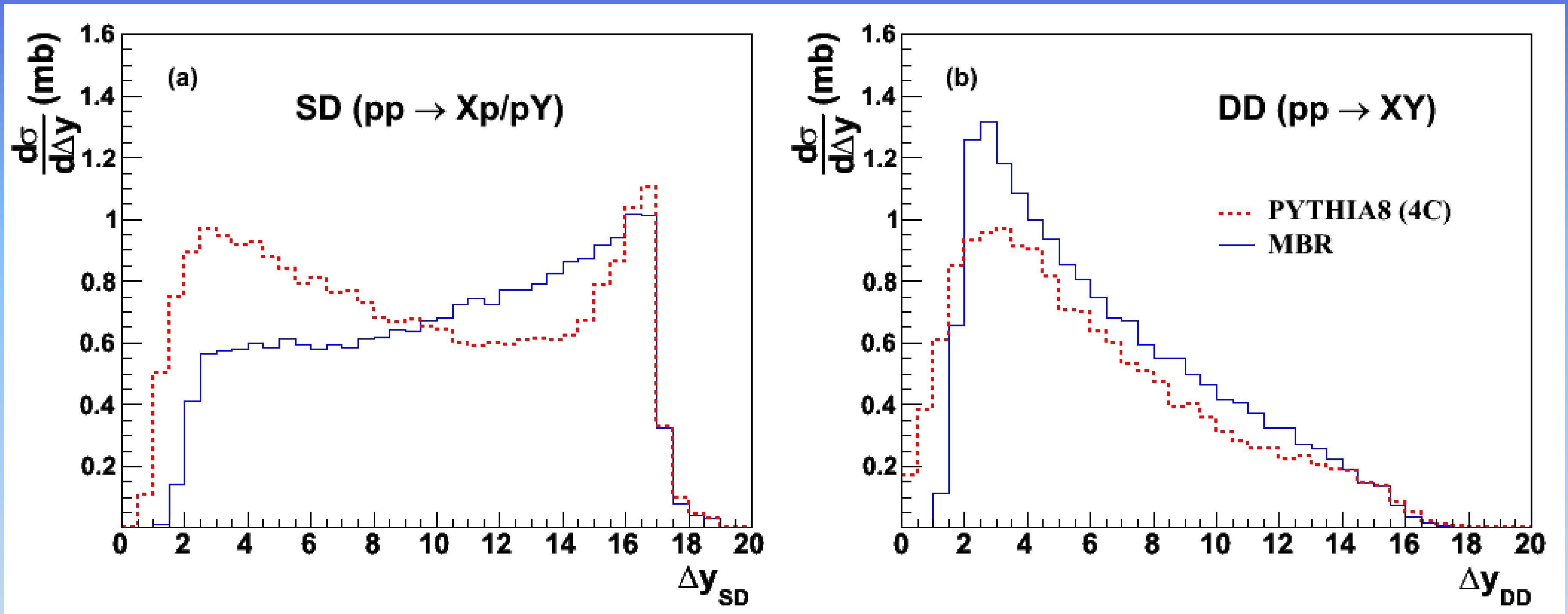


- ❑ Supress x-sections at small gaps by a factor S using the error function with Δy_S=2 for SD and DD, and $\Delta y=\Delta y_1+\Delta y_2$ =2 for CD (DPE).

$$S = \frac{1}{2}\left[1 + erf\left(\frac{\Delta y - \Delta y_S}{\sigma_S}\right)\right]$$

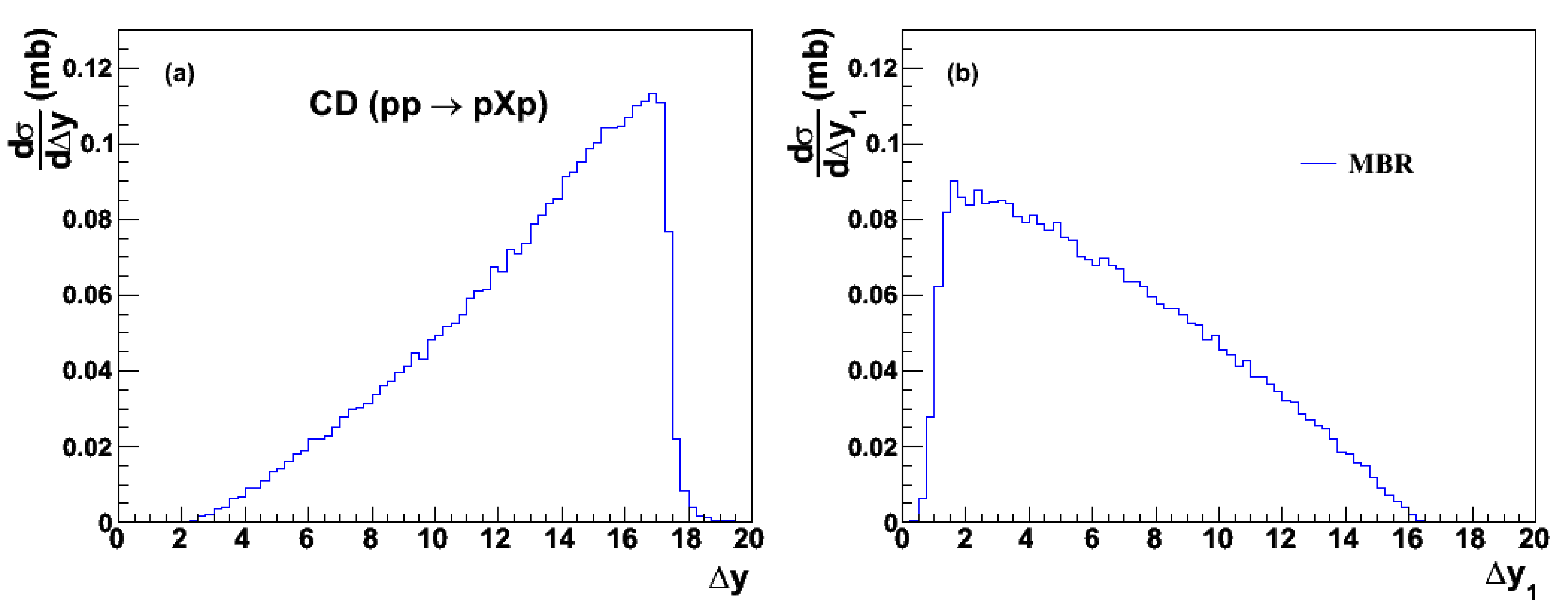
SD and DD at 7 TeV

MBR vs PYTHIA8-4C



- The differences between the PYTHIA8(4C) and MBR predictions are mainly due to the $(1/M2)^{1+\varepsilon}$ behavior, with ε=1.104 in MBR vs 1,08 in PYTHIA8(4C).

CD (DPE) x-sections at 7 TeV versus (a) Δy=Δy1+Δy2 and (b) Δy1



- Both figures are MBR predictions with a Δy=2 cut-off in the error function.
- The normalization is absolute with no model uncertainty other than that due to the determination of the parameters in the formulas as determined from data

Thank you for your attention

References in arXiv:1205.1446v1 [hep-ph]

[1] K. Goulianos, *Hadronic diffraction: where do we stand?*, hep-ph/0407035; K. Goulianos, *Diffraction in QCD*, arXiv:hep-ph/020314.

[2] T. Sjöstrand, S. Mrenna and P. Skands, JHEP05 (2006) 026, Comput. Phys. Comm. 178 (2008) 852, arXiv:hep-ph/0603175,arXiv:0710.3820.

[3] R. J. M. Covolan, K. Goulianos, J. Montanha, Phys. Lett. B **389**, 176 (1996).

[4] K. Goulianos, *Diffraction, Saturation and pp Cross Sections at the LHC*, arXiv:1105.4916.

[5] A. Donnachie, P. V. Landshoff, Nucl. Phys. B **303**, 634 (1988).

[6] K. Goulianos, Phys. Lett. **B358**, 379 (1995).

[7] T. Affolder et al. (CDF Collab.), *Double Diffraction Dissociation at the Fermilab Tevatron Collider*, Phys. Rev. Lett. **87**, 141802 (2001).

[8] D. Acosta et al. (CDF Collab.), *Inclusive double Pomeron exchange at the Fermilab Tevatron $\bar{p}p$ collider*, Phys. Rev. Lett. **93**, 141601 (2004).

[9] R. J. M. Covolan, K. Goulianos, J. Montanha, Phys. Rev. D **59**, 114017 (1999).

10] `http://en.wikipedia.org/wiki/Error_function`

11] K. Goulianos, *Diffractive interactions of hadrons at high energies*, Phys. Rep. 101, 169 (1983).

Volume 193, number 1 PHYSICS LETTERS B multiplicities 9 July 1987